7.—The Dalgety Downs chondritic meteorite

by G. J. H. McCall*

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Abstract

The Dalgety Downs meteorite is now known to have been erroneously described some twenty years ago as a stony iron. A large amount of new material lately recovered from the site of the original find shows it to have the character of an olivine-hypersthene chondrite. A full description is given here, and some unusual features are mentioned—the deformation structure, the unusually large individual hypersthene chondrule, and the lamellar twinned pyroxene.

Introduction

The Dalgety Downs meteorite is recorded by Prior and Hey (1953 p.97-98) as a stony-iron (fine grained siderolite), and by Mason in a list of mesosiderites, together with Bencubbin (1962 p.122). While Bencubbin is a stony-iron meteorite but not a mesosiderite (Lovering 1962; McCall and de Laeter 1965), there is now no doubt that Dalgety Downs is a common chondrite. The error seems to be due to a mistaken practice of referring to any meteorite containing both silicate and iron as a stony iron, irrespective of the proportions.

Interest in this record was revived early in 1963, when Dr. B. H. Mason of the American Museum of Natural History sought information from the Director of the Western Australian Museum concerning this and three other "lost" meteorites recorded by Prior and Hey (1953). Enquiries were started and a trace of the actual material reported in 1942 (Anon.) was discovered in the form of a small, iron-stained chip in the collection of the Government Chemical Laboratories, Perth. With surprise it was noted that this chip had the characteristics of a chondrite, and thin section study confirmed this view.

In July 1963 two further developments occurred. The writer was shown a specimen of 3.3 lbs weight in the collection of the School of Mines, Kalgoorlie. This was labelled "Ashburton Downs" (the name of a sheep station to the north of Dalgety Downs). A portion of this material had been removed by H. H. Nininger in an exchange transaction and from this B. H. Mason had already determined the olivine as Fa_{25} (Mason 1963 p.1014). During this same month Dr Mason and Mr. E. P. Henderson of the Smithsonian Institution, Washington, were directed to the site by the actual finder and recovered nearly five hundred pounds of fragments. Comparison of this new material with that labelled "Ashburton Downs" revealed an astonishing similarity, in chondritic structure, fracturing and veining, and orientation of the metallic flecks. It was so marked that coincidence seemed improbable, and the possibility that Ashburton and Dalgety Downs were one and the same meteorite was suggested. Confirmation came shortly afterwards when it was discovered that some fragments known to come from Mount Egerton (Prior and Hey 1953 p.248; McCall, 1965) had been wrongly labelled at the Kalgoorlie School of Mines: and, in the same register that accession of these fragments had been recorded, was found the record of accession of a specimen identical with that labelled Ashburton Downs, but entered as "from Mr. P. A. Healy, Dalgety Downs". As Mr. Healy has been associated with but the one find, and there is no trace of any other material of this nature in the collection, it seems reasonable to assume that the faulty recollection of some

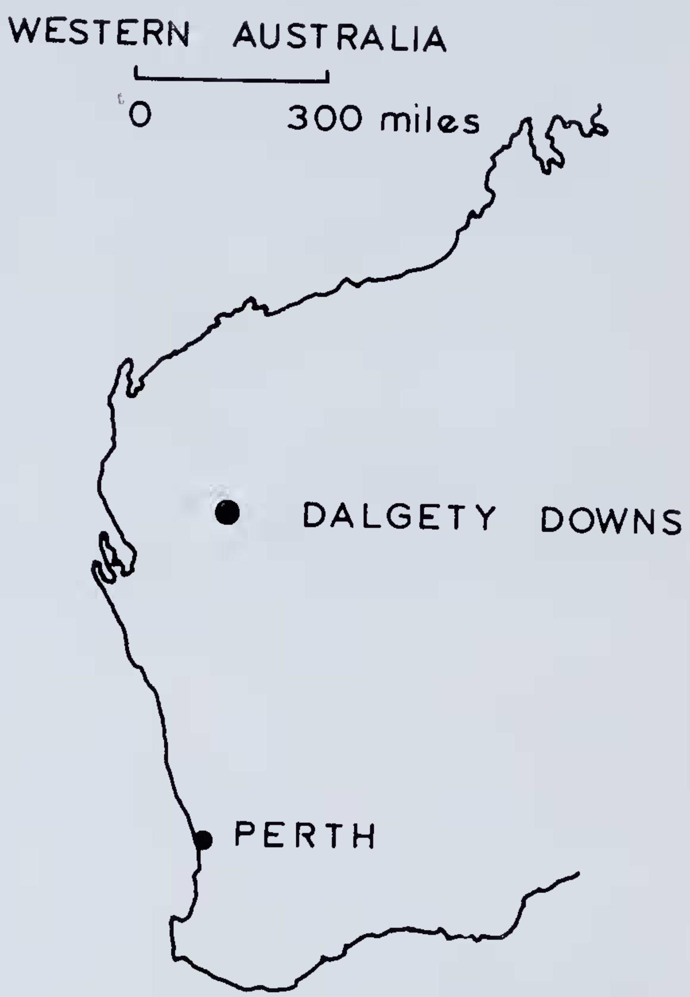

Figure 1.—Location of the Dalgety Downs meteorite recovery.

* Department of Geology, University of Western Australia.

person unknown when labelling the specimens some time after accession (it was wartime and strict routines had probably lapsed), allowed the name Ashburton Downs to enter the literature. It should now be regarded as nothing more than a synonym for Dalgety Downs.

In June 1964 Mr. W. H. Cleverly, Head of the Geology Department, School of Mines, Kalgoorlie and curator of the Kalgoorlie collection, visited the site and made a sketch of distribution

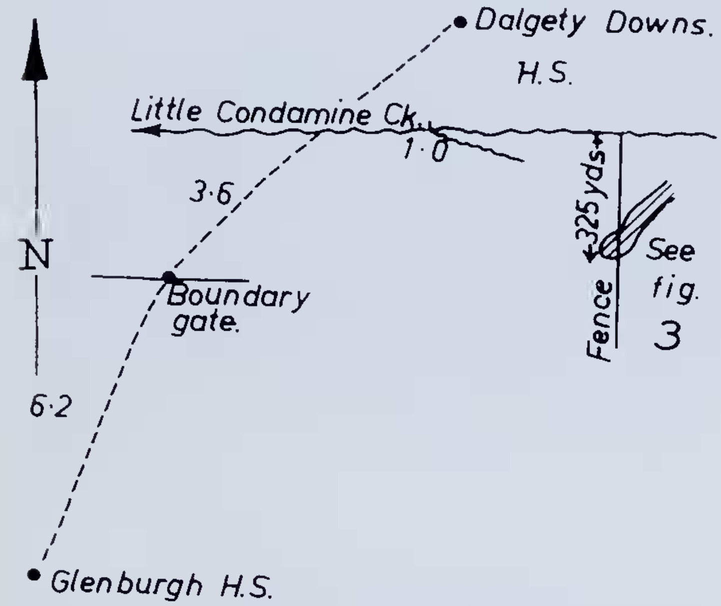

Figure 2.—Location of the Dalgety Downs meteorite recovery. The figures show distances in miles.

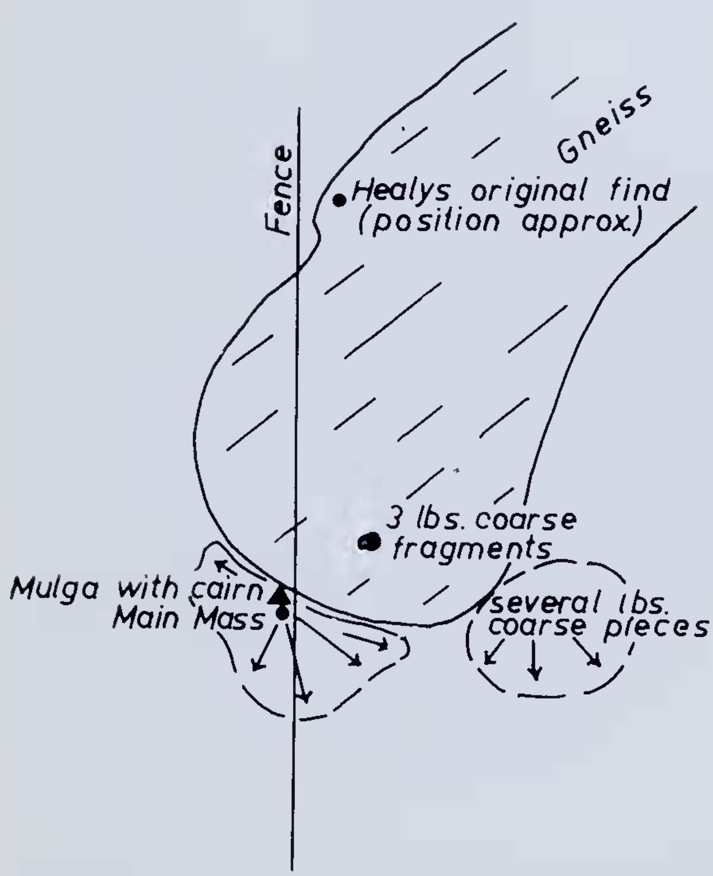

Figure 3.—Enlargement of part of Figure 2, showing details of recovery locations.

of fragments from his own observation and that of the finder, Mr. Healy, who accompanied him. His sketch, which is reproduced in Figures 2 and 3, is accepted as correct by Dr. Mason (written communication) who, however, adds that he found some outlying fragments up to 150 yards from the main mass. Mr. Cleverly recovered a further 90 lbs of fragments, all that he could transport, and believes that still more remain on the ground. The total recovery to date is:—

a "Dalgety Downs", Healy recovery	Government Chemical Laboratories, Perth—small chip
b "Ashburton Downs", Healy recovery ...	School of Mines, Kalgoorlie, Western Australian Museum, University of Arizona, Tempe, American Museum of Natural History, British Museum, Natural History—8 lbs.
c "Dalgety Downs", Mason and Henderson recovery	Western Australian Museum —9 lbs, American Museum of Natural History: Smithsonian Institution, Washington—472 lbs.
d "Dalgety Downs", Cleverly recovery	School of Mines, Kalgoorlie—90 lbs.
	Total—c. 579 lbs

The recovery of approximately 579 lbs of material makes this the largest recovery of stony meteorite material in this State and the second largest such recovery in Australia; and how much additional material remains out at the site is not known.

The find

The position of the find is about three miles south by east of the homestead of Dalgety Downs sheep station in the Gascoyne District of Western Australia: Latitude 25° 21' South; Longitude 116° 11' East (Fig. 1). The find was made in 1941 and Mr. P. A. Healy, the finder, believed that he had picked up some terrestrial rock detritus and was most surprised to learn of its true nature. Dr. Mason reports that even he and Mr. Henderson did not immediately recognise the brownish, weathered material scattered over the surface as the meteoritic material they sought, for it had the appearance of lateritic float material all too familiar in this State.

The distribution of the fragments on the ground (Figs. 2 and 3) suggests a flight trajectory bringing the meteorite in from the north-north-west. None of the fragments was appreciably buried.

Most of the material recovered by Mason and Henderson was part of a single conical mass which fell apart into a mass of fragments as it was excavated. The point of the cone was downwards, and the mass was evidently in the position of fall. Original surface showing regmaglypts was present on all buried surfaces, but the part level with the ground surface was broken and fragmentary. It appears probable that the meteorite landed as a single mass and the impact caused shattering and the distribution of small fragments around the main mass; this distribution may have been modified into a more widespread pattern by the agency of sheet flood erosion consequent on the occasional extremely heavy rains which are a feature of the local climate.

Figure 4.—Large fragment (Wt. 11 kg) showing regmaglypts. (No.41388 American Museum of Natural History Meteorite Collections.) (Photo American Museum of Natural History).

Figure 5.—Large fragment (Wt. 59 kg) showing elongated regmaglypts. A white caliche encrustation covers the bare surface of the stone; in spite of the regmaglypts there is no fusion crust preserved. (No.4189 American Museum of Natural History Meteorite Collections.) (Photo American Museum of Natural History).

Physical properties and surface features

The individual fragments range from a foot or more across to pebble size. All have a deep ferruginous weathered surface layer and in many this extends right through the mass. However, on cutting, some of the larger masses reveal relatively fresh, greenish core material (Fig.6). There is not a trace of fusion crust and one must assume that it has decomposed and flaked off during a long period of exposure to the terrestrial atmosphere—otherwise there is no reason why it should not be present since some of the surfaces of the larger masses are original ablation surfaces, revealing distinct patterns of regmaglypts (Figs. 4 and 5). The distribution of fragments on the ground and the relation of ablation—marked surfaces to secondary surfaces suggests that the mass fractured and disintegrated very late in its atmospheric flight, either just before impact as the preceding compression wave rebounded off the ground or at the moment of impact. The latter seems much more likely, but there is no certainty that it was a single mass; attempts to reconstruct the mass in the same manner as the Woolgorong stony meteorite (McCall and Jeffery 1964) would be quite futile considering the number of fragments and their weathered state.

Many of the masses are coated with creamy white calcareous caliche (Fig. 5), due to the action of surface water.

The specific gravity of the fresh core material is 3.50, a figure quite typical of this class of meteorite (Average 3.51; Mason 1962 p. 95).

No normal-sized chondrules show up to the naked eye on fresh surfaces (Fig. 6), but rounded and distorted chondrules are apparent on cut faces of weathered specimens. One giant chondrule (diameter 1.0 cm) does however show on the cut face of the specimen formerly labelled "Ashburton Downs" and sub-parallel aligned nickel-iron and troilite flecks are apparent on most fresh cut surfaces (Fig. 6). The inconspicuous nature of the chondritic structure seems to be due to secondary brecciation and overall fineness of texture rather than to recrystallisation processes.

Microscopic examination

As with many fine-textured meteorites the examination of the gross texture is best carried out with a binocular microscope using oblique

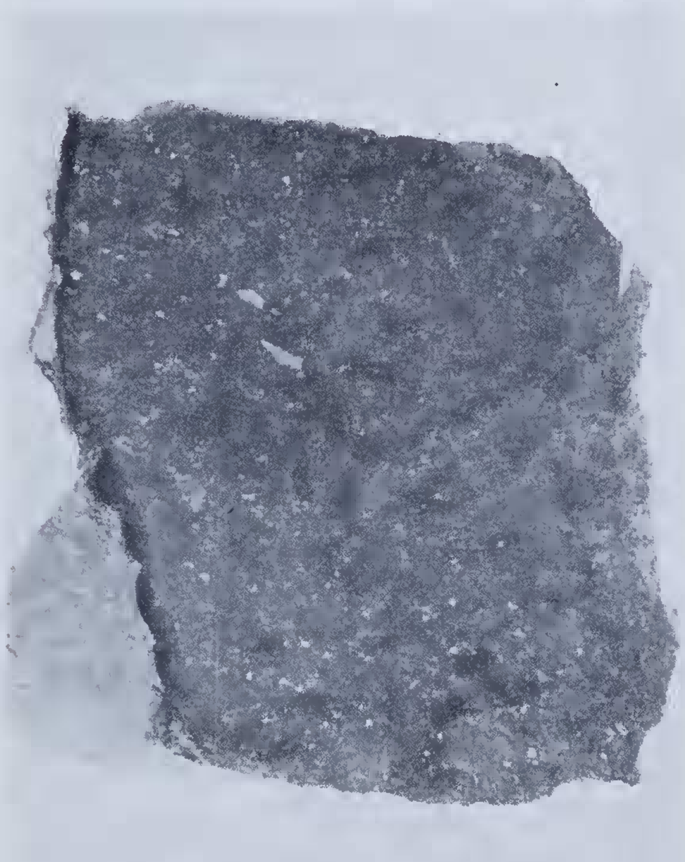

Figure 6.—Dalgety Downs; cut section showing sub-parallel orientation of metal flecks and a giant hypersthene ehrondrule—(W.A.M. No.12173 x1.2).

reflected light. The deformation texture so observed is most interesting; it has been noted above that nickel-iron and troilite specks appear to the naked eye to possess a sub-parallel orientation, and with increased magnification the nature of this deformation structure becomes apparent. The mass is traversed by sets of hair-line fractures which, in certain areas, are very closely spaced, while in othe areas they are not conspicuous. In the vicinity of close concentrations of such fine cracks the chondrules are broken and deformed into ellipsoids (Fig.7A), while the nickel-iron and troilite tends to form compound aggregates or discrete specks aligned roughly parallel to the cracks. The troilite tends to be associated with the nickel-iron aggregates as subordinate specks or partial rims (Fig. 8A and B), the latter relationship suggesting that it was crystallised later than the nickel-iron. Careful examination shows that the troilite actually fills the cracks as thread-like veinlets or shows marked concentration round intersections of cracks (Fig. 8 A). The nickel-iron has suffered displacement on some cracks which are in fact microfaults (Fig. 8 C), but, though nickel-iron aggregates are elongated in a sub-parallel manner due to deformation under stress, it does not, in contrast to the troilite, infill the cracks as a later veining material.

This fabric seems to be related to two principal sets of fractures and indicates that the meteorite suffered some form of directed stress, and that not so late in its history that troilite could not be mobilised and recrystallised along the fracture lines. It is generally accepted that such troilite crystallisation would not occur during the period of atmospheric ablation which usually results only in thin intrusions of glass veining the body of the meteorite, projections of the fusion crust (McCall and Jeffery 1964 p.36). However the remote possibility of troilite recrystallisation during ablation cannot be dismissed outright since there is evidence of possible recrystallisation of troilite in the fusion crust of another Western Australian meteorite (Frenchman Bay: McCall 1966). Yet the size of the Dalgety Downs mass seems against any such effect and we can reasonably conclude that we are seeing the results of fracturing and recrystallisation during a period of stress or shock suffered by the rock mass within the parent cosmic body before the meteorite was isolated in the relatively small fragment of that body which eventually encountered the Earth. It is a type of directed texture quite different from those lately discussed by Dodd (1964), those being primary penetrative textures related to "deposition", not secondary deformation. This texture qualifies the Dalgety Downs meteorite for the description "unevenly veined and brecciated" but does not appear to be in any way related to "deposition".

Under reflected light the glass areas contrast strongly with the ore minerals, showing pale brown and non-reflectant, and it is clear that there is appreciable glass in this meteorite though much of it is turbid and near-opaque, due to devitrification.

Thin section examination shows again, the patchy distribution of deformation. In some areas the chondrules preserve their spherical form (Fig. 7 B). The tendency for ore minerals and ironstained amorphous material (after glass?) to swathe chondrules is apparent (Fig. 7 B) though not so obvious as in some not-recrystallised chondrites.

The silicate minerals of the chondrules include *olivine*, present in the form of euhedral or subhedral crystals and aggregates without crystal outlines (e.g., in barred chondrules); *hypersthene* present in subhedral grains and fibrous aggregates; and rare grains of a *lamellar-twinned pyroxene* similar to that described and figured by Tschermak (1883 Fig.58). The indistinctness of the lamellae and (Fig.9A) stronger positive relief distinguish this mineral from plagioclase. The extinction angle of the lamellae is about 40°. B. H. Mason (written communication) considers this to be a pigeonitic clinopyroxene (see McCall 1966 for discussion). Modal oligoclase cannot be detected with any confidence in this meteorite by normal microscopic methods and one must conclude that in these glassy chondrites it is represented in the glass component (and possibly some of the anorthite is represented in the pigeonitic pyroxene), for normative plagioclase is always apparent in chemical analyses (McCall and de Laeter 1965 p. 30-32) and in much the same amount as in strongly recrystallised chondrites such as Woolgorong (McCall and Jeffery 1964), in which crystalline felspar is abundantly apparent. However there is some finely granular material, of very low birefringence and refractive

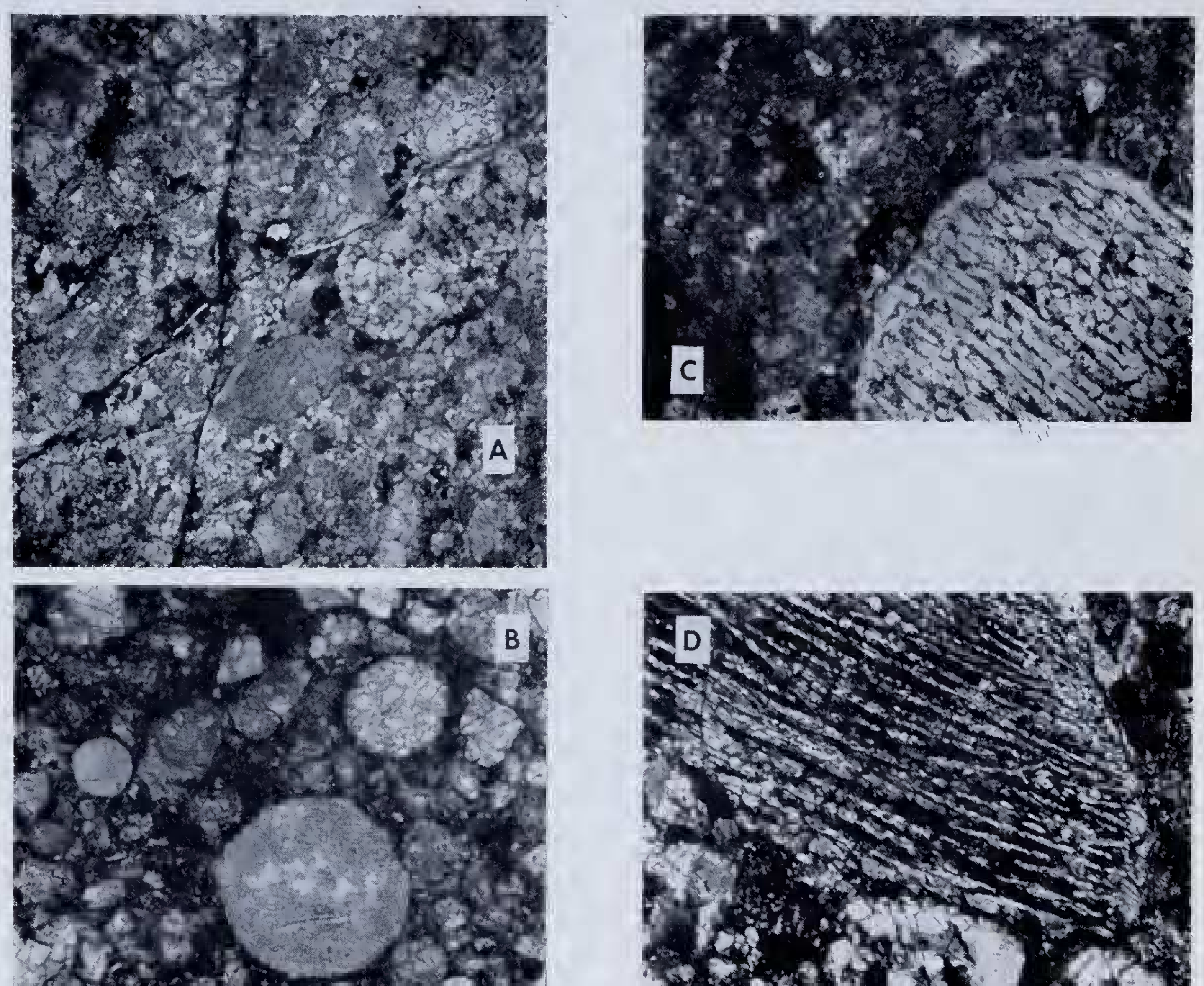

Figure 7.—A.—General view of the chondritic texture intersecting microfaults, with troilite (black) concentrated at the point of intersection and filling the veins. The ellipsoidal form of two chondrules, a fan chondrule and a granular chondrule (middle, right), suggests that the stress which caused the fracture also deformed the once spherical chondrules. (x6.2, plane polarised light). B.—Spherical chondrules in an area away from fractures, including a finely grated type (lower, centre), a cryptocrystalline fan chondrule of orthopyoxene (middle, left) and a microporphyritic chondrule containing interstitial glass, (upper right). (x16.5, plane polarised light). C.—Monsomatic barred chondrule with annular rim. This large chondrule contains crystalline material of low relief and low birefringence between the bars. (x16.5, crossed nicols). D.—Monosomatic barred chondrule. Olivine forms the bars as in all monosomatic varieties but there is interstitial granular material of low birefringence and low relief (although it is crammed with inclusions which give a deceptive appearance of high relief except under high power) (x40, crossed nicols).

index comparable with felspar, sparsely represented in the interstices between olivine and pyroxene grains (Fig. 9B) and in selvedge material of one large barred chondrule. It shows three cleavages at 60° to one another. It has not been identified. Mason (written communication) has made an acid insoluble concentrate from this meteoritic material, and detected some fine-grained plagioclase of mean refractive index 1.540 (An_{15}). The identification of this plagioclase has been confirmed by X-ray powder diffraction photograph. He has also used a microprobe to show that the glass in glass-containing chondrites is probably of felspar composition, closely resembling that of oligoclase.

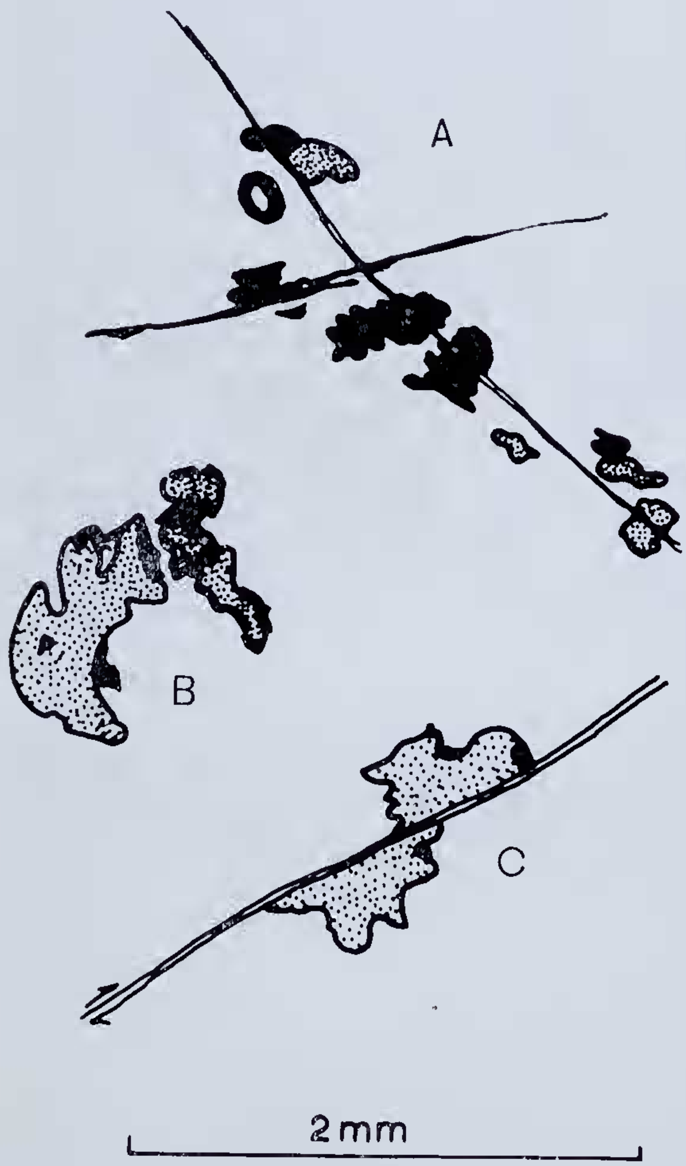

Figure 8. A.—Intersection of fracture planes showing concentration of troilite (black) near the intersection, and in the actual cracks, while kamacite (stippled) shows no such concentration. B.—Troilite (black) fringing kamacite (stippled). C.—Kamacite (stippled), fringed by troilite (black) and displaced by a microfault.

There is some translucent brownish glass within the chondrule interstices, though it is to some extent devitrified; most of the glass is completely devitrified.

Amongst the chondrules the following types are apparent:—

Monosomatic chondrules. These include chondrules formed of single crystals of pyroxene or olivine, mostly rather irregular chondrules showing no complexity of structure. Other monosomatic chondrules are formed of wide bars and narrow screens in the core, and a rim somewhat wider than the bars of the core (Fig. 7C). They extinguish in an undulose manner due to strain but are formed of a single crystal of olivine. The screens are mostly of glass or cryptocrystalline material after glass, but one large individual shows screens of finely-crushed olivine granules and the mineral of low refractive index and birefringence mentioned above (Fig. 7C). There is also present some irresolveable material which may be glassy or cryptocrystalline.

Polysomatic chondrules. Far more numerous than the monosomatic types, these include: granular aggregates of olivine or pyroxene alone, but with grains showing different orientation; aggregates of olivine phenocrysts set in glass or fine cryptocrystalline aggregates after glass (Fig. 7B); aggregates of pyroxene and olivine together, with or without interstitial glass or cryptocrystalline material; fan chondrules of olivine and, more often, orthopyroxene in slender fibres (both single excentric fans and compound aggregates of several fans in one chondrule are seen).

Among both olivine and orthopyroxene chondrules are some which show a finely-barred structure and include central cores of glass or cryptocrystalline material (Fig. 7C). There are also some finely barred chondrules composed of an olivine grid in optical continuity, and separated by granules of a weakly birefringent mineral with different orientation and peppered with minute droplet inclusions (Fig. 7D). These may be pyroxene or may be the unidentified mineral mentioned above. A most unusual feature is the giant chondrule (Fig. 9C; McCall and de Laeter 1965 Plate XIXa), composed of granular hypersthene; its oval outline seems to indicate that it is a chondrule not an achondrite enclave.

There is no significant evidence of recrystallisation except the partial or complete development of granules instead of glass in some barred chondrule selvedges, and the anisotropic (cryptocrystalline) character of most of the interstitial material that once was glass, and is now in varying stages of devitrification. It would seem fair to assess this as a chondrite showing considerable devitrification but no significant recrystallisation to obliterate the chondrules.

Modal composition

The mode was measured using a graticule on both reflecting surface and thin section, with the following result:—

Nickel iron, plus troilite	8-10%	(kamacite/troilite 3/1)
Silicate	90-92%	

Approximate silicate composition: olivine 65%; orthopyroxene (hypersthene) 25%; clinopyroxene—trace in schiller inclusions; unidentified mineral of low refractive index-trace; glass 2% (mostly devitrified).

These measurements are, of course, very approximate due to the variable nature of the material.

Figure 9.—A.—Lamellar pyroxene grain, (x63, crossed nicols). B.—Pool of a mineral of low relief and birefringence, appearing like untwinned felspar but showing anomalous cleavages (x63, plane polarised light). C.—Giant orthopyroxene chrondrule (x6.3, plane polarised light).

Chemical analysis

A full chemical analysis was carried out by Dr. A. A. Moss at the British Museum, Natural History, London, and is reproduced by McCall and de Laeter (1965 p.30-32). The following ratios derived from this chemical analysis:—

(a) Molecular MgO/FeO = 3.55 (bulk; 1/7 in magnetic fraction).

(b) Nickel/iron = 1/6.57.

place this stony meteorite within Prior's class 3—(olivine-hypersthene chondrites). This was confirmed by X-ray diffraction using the method of Yoder and Sahama (1957), values obtained for the olivine being:—

Dalgety Downs (Ashburton Downs)—Fa_{25} (Determined by B. H. Mason, American Museum of Natural History).

Dalgety Downs (Mason and Henderson—Fa_{24} recovery) (Determined by B. H. Mason, American Museum of Natural History).

These are typical values for olivine in olivine hypersthene chondrites (Mason 1963).

Acknowledgements

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